# MODAL MAPPING IN A COMPLEX SHALLOW WATER ENVIRONMENT

George V. Frisk
Department of Applied Ocean Physics and Engineering
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
Telephone: (508) 289-2383, Fax: (508) 457-2194
E-mail: gfrisk@whoi.edu
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## LONG-TERM GOALS

The long-term goal of this research is to increase our understanding of shallow water acoustic propagation and its relationship to the three-dimensionally varying geoacoustic properties of the seabed.

## OBJECTIVES

The scientific objectives of this research are: (1) to develop high-resolution methods for characterizing the spatial and temporal behavior of the normal mode field in shallow water; (2) to use this characterization as input data to inversion techniques for inferring the acoustic properties of the shallow water waveguide; and (3) to use this characterization to improve our ability to localize and track sources.

## APPROACH

An experimental technique is being developed for mapping the wavenumber spectrum of the normal mode field as a function of position in a complex, shallow water waveguide environment whose acoustic properties vary in three spatial dimensions. By describing the spatially varying spectral content of the modal field, the method provides a direct measure of the propagation characteristics of the waveguide. The resulting model maps can also be used as input data to inverse techniques for obtaining the acoustic properties of the waveguide. The experimental configuration consists of a fixed source radiating one or more pure tones to a field of freely drifting buoys, each containing a hydrophone, GPS and acoustic navigation, and radio telemetry. In this context, two-dimensional modal maps in range *and* azimuth, as well as three-dimensional bottom inversion in range, depth, *and* azimuth, become achievable goals.

## WORK COMPLETED

The Modal Mapping Experiment (MOMAX) was conducted aboard the R/V Endeavor during the period 21 March - 3 April 1997. A series of eight experiments was carried out in the East Coast STRATAFORM/SWARM area off the New Jersey coast in about 70 m

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of water. Three drifting buoys received signals at ranges of up to 10 km from sources deployed in one of two configurations: (1) an NRL J15-3 source suspended from the ship (drifting or underway) at a depth of 30 m and transmitting pure tones at 50, 75, 125, and 175 Hz; and (2) a Webb source moored 1 m above the bottom and radiating pure tones at 200 and 300 Hz. In both cases, the nominal source level was 170 dB re 1 $\mu$Pa @ 1 m. In addition to the acoustic measurements, the following environmental data were recorded: (1) 3-6 kHz chirp sonar subbottom data along every buoy and source track; (2) numerous CTD casts throughout the region; and (3) Seamon temperature logger data at several depths on each drifter buoy and on the Webb source mooring.

## RESULTS

A preliminary examination of the measurements indicates that the data are of extraordinarily high quality and offer great promise for achieving the goals of the research. It was found that the application of kinematic moving-base-station differential processing to the ship and buoy GPS positions, each with absolute accuracy of about 100 m, permits the determination of the relative range between source and receiver to an accuracy of less than 1 m. This positioning accuracy then enables the effective creation of a synthetic aperture array for frequencies of up to several hundred Hz. Several preliminary modal maps have been generated by FFT beam forming the data over a succession of sliding sub-apertures. The range-dependent environment, as seen in the chirp sonar data, is reflected in the noticeable evolution of the modal peaks with range.

A striking feature in the data is the remarkable stability and regularity of the phase, even though the magnitude reflects a complex multimodal interference pattern. This phase behavior occurs even at the higher frequencies and higher source/receiver speeds (up to 3 kts) measured in the experiment. A preliminary calculation indicates that the phase is dominated by the term $k_o r$, where $r$ = source/receiver range, $k_o = w / c_o$, $w$ = frequency, and $c_o$ = 1500 m/s. This simple phase model appears to be effective even in a complex multipath environment with complicated sound velocity profiles in the water column and bottom. This model has enabled us to make accurate estimates of the relative source/receiver speed from measurements of the time rate-of-change of the phase. This observation has significant implications for source localization and tracking, particularly when the data from several buoys are incorporated.

## IMPACT/APPLICATIONS

The experimental configuration consisting of a CW source and freely drifting buoys will provide a simple way to characterize a shallow water area and may be useful in survey operations. In addition, the planar, synthetic receiving array may offer an effective new technique for localizing and tracking CW sources in shallow water.

## TRANSITIONS

The synthetic aperture technique and Hankel transform inversion methodology which underlies the modal mapping method has been implemented in the ACT II experiment, sponsored by DARPA and ONR.  This approach has also been adopted by several research groups internationally.

## RELATED PROJECTS

MOMAX was conducted in the same area off the New Jersey coast where the ONR-sponsored STRATAFORM and SWARM experiments were carried out.  The extensive geophysical, seismic, acoustic, and oceanographic data obtained in the latter two experiments will be used to ground truth the MOMAX measurements.

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